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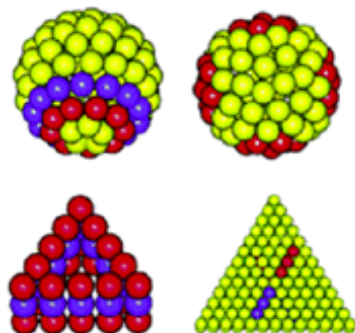
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## Patching together nanomaterials

**To use nanoparticles as the building blocks for new materials and device, you need a way of assembling them. Giving them sticky patches allows access to a wide range of self-assembled structures.**

PHILIP BALL



Patchy particles. Reprinted with permission from ref. 1. Copyright (2004) American Chemical Society.

Self-assembly of nanoparticles is one of the most attractive ways to build nanostructures. But the big challenge is to program the particles to assemble the way you want them to. Researchers at the University of Michigan in Ann Arbor have explored a rather general way to direct such an assembly process into a wide range of structures, including chains, sheets, rings and three-dimensional clusters with various symmetries<sup>1</sup>.

Zhenli Zhang and Sharon Glotzer figured that nanoparticles whose surfaces are

patterned with 'sticky patches' might group together into well defined shapes. This can be considered to mimic the way that viruses typically self-assemble into complex shapes owing to spatially and chemically specific interactions between the discrete protein molecules that constitute their coats. Building blocks of this sort, which are imbued with the information needed for their spontaneous assembly, have been termed 'programmed matter'.

Zhang and Glotzer have studied this problem using computer simulations. But what are the prospects for actually making such 'patchy' nanoparticles? George Whitesides' group at Harvard has synthesized particles at both the macro- and the microscales that have hydrophobic and hydrophilic regions on different parts of their surfaces. Aggregation of, say, the hydrophobic regions in water drives self-assembly of these particles into a variety of structures, such as stacks and sheets<sup>2</sup>. Whitesides has even constructed functioning macroscopic electronic circuits this way<sup>3</sup>.

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Surface patterning at the nanoscale is harder. Whitesides and co-workers have succeeded in making spherical nanoparticles that are coated with a gold film on only one hemisphere, permitting the synthesis of two-faced 'Janus' particles<sup>4</sup>. Francesco Stellacci and co-workers at the Massachusetts Institute of Technology have reported metal nanoparticles coated with mixtures of organic ligands that spontaneously phase-separate to create surface patterns with features as small as 5 Å ([ref. 5](#)).

As well as relying on generalized surface forces (such as hydrophobic interactions), one can functionalize nanoparticles with molecular groups that exhibit selective molecular recognition, so that particles will aggregate through lock-and-key interactions (see, for example, [refs 6, 7](#)). It remains a challenge in this case, however, to position the recognition sites in precise arrangements on the particle surfaces.

Zhang and Glotzer have looked at the types of generic structures that will be formed by 'patchy' particles with attractive patches that have various simple shapes, such as blobs at opposite poles of spherical particles, or bands around their equator. They admit that, although ideally one might simulate such nanoparticles at the level of individual atoms, this would be computationally very expensive, because thousands or millions of atoms or molecules might be involved on each individual particle.

So they take a 'coarse-grained' approach in which the patchy particles are made up of smaller spheres that each represent perhaps hundreds of atoms. The 'sticky' spheres might interact with one another either by non-specific forces typically used to model intermolecular attractions such as van der Waals forces, or by more selective forces in which one type of sphere will stick only to another 'complementary' type.

The researchers find that the patchy particles, dispersed in solution, generally undergo a sharp phase transition as the temperature is lowered, from a liquid-like, more or less dissociated state to an aggregated state whose structure depends on the arrangement of the patches and the shape of the particles. For example, spherical particles with a patch at each pole will aggregate into chain-like structures — basically a kind of polymerization. With four patches, placed around the particle equators at the corners of a square, the result is instead a sheet in which the particles are packed in square arrays.

Equatorial rings of 'stickiness', meanwhile, generate sheets with hexagonal close-packing. By using ring-like patches comprised of 'atoms' with specific recognition properties it is possible to engineer more complex sheet structures, such as regular binary arrays of different types of particle. To create three-dimensional structures, Zhang and Glotzer positioned their patches asymmetrically — for example, placing discrete patches in just one hemisphere. This enabled them, for example, to make clusters with icosahedral symmetry. This shape is common in viruses, although it is also found as a transient species in freezing processes<sup>8</sup> and in the aggregation of spherical particles with non-directional interactions<sup>9</sup>. Zhang and Glotzer found that asymmetric patches may also lead to ring-shaped aggregates, and they could vary the size of the rings by varying the precise location of the patches.

Zhang and Glotzer also considered the self-assembly of patchy particles with triangular plate shapes. By placing patches on the faces and sides of the triangles, they could program them to assemble into stacks, sheets and twisted 'staircase' structures.

They point out that self-assembly into sheets could be important for making

new types of material, or for making ordered arrays for optical and electronic applications. Three-dimensional networks, for example consisting of interlinked chains, might be useful as porous materials (ultra-light aerogels are basically webs of self-assembled chains of microparticles) and as scaffolds for assembling other components. The key point here is that the building blocks are generally simple and identical; the art of design comes from understanding how the collective behaviour of these units depends on the precise placement of their sticky patches.

## References

1. Zhang Z. & Glotzer S. C. Self-assembly of patchy particles. *Nano Letters* advance online publication (2004)
2. Bowden N. B., Weck M., Choi I. S. & Whitesides G. M. Molecule-mimetic chemistry and mesoscale self-assembly. *Acc. Chem. Res.* **34**, 231–238 (2001)
3. Terfort A. & Whitesides G. M. Self-assembly of an operating electrical circuit based on shape complementarity and the hydrophobic effect. *Adv. Mater.* **10**, 470–473 (1998)
4. Love J. C., Gates B. D., Wolfe D. B., Paul K. E. & Whitesides G. M. Fabrication and wetting properties of metallic half-shells with submicron diameters. *Nano. Lett.* **2**, 891–894 (2002)
5. Jackson A. M., Myerson J. W. & Stellacci F. Spontaneous assembly of subnanometre-ordered domains in the ligand shell of monolayer-protected nanoparticles. *Nature Mater.* **3**, 330–336 (2004)  
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6. Mirkin C. A., Letsinger R. L., Mucic R. C. & Storhoff J. J. A DNA-based method for rationally assembling nanoparticles into macroscopic materials. *Nature* **382**, 607–609 (1996)
7. Banerjee I. A., Yu L. T. & Matsui H. Location-specific biological functionalization on nanotubes: attachment of proteins at the ends of nanotubes using Au nanocrystal masks. *Nano Lett.* **3**, 283–287 (2003)
8. Frank F. C. *Proc. Roy. Soc. A* **215**, 43 (1952)
9. Beck T. L., Jellinek J. & Berry R. S. Rare gas clusters: solids, liquids, slush, and magic numbers. *J. Chem. Phys.* **87**, 545–554 (1987)

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